A212

PATENT SPECIFICATION

Application Date: Dec. 10, 1919. No. 30,930/19.

156,396

Complete Accepted: Jan. 13, 1921.

COMPLETE SPECIFICATION.

An Improved Method of Treating Shale and Recovering Oil therefrom.

We, Wilson Woods Hoover, Lawyer, and Thomas Ellis Brown, Engineer, both of 99, Nassau Street, New York City, New York, U.S.A., do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

Our invention relates more particularly to a class, *sui generis*, in which a sub-surface zone, permeable to a heating medium, is produced in a normally impermeable oil shale formation, without mining the same and the bituminous content of such zone is treated *in situ*, for its conversion into petroleum and the recovery of the latter or of its products.

In the present state of the art the oil shale is quarried, or mined, or isolated columns are exposed and enclosed for treatment the material excavated in the process being subjected to surface distillation.

In the United States Survey Press Bulletin No. 376 the statement appears: "The (oil) shale contains a great mass of partly bituminized vegetable matter, which can be converted into oil by heat," thus distinguishing between the content of an oil shale and that of an oil bearing sandstone or limestone.

Among other objects of our invention is to gain access to a sub-surface zone of oil shale for the introduction of explosives and other purposes, by means of openings or wells of limited cross-section such as drilled oil wells; also to explode charges of explosives, introduced therein through such wells, as may be required, in quantities sufficient to render permeable, by fracture of the material therein, to a heating medium and for that purpose to so drill a series or group of contiguous wells that the fractures produced in the formation in such zone by the explosives in the respective wells may intercommunicate; also to introduce a heating medium into and to circulate the same through such zone and to thereby convert the bituminous content into petroleum or shale oil and to recover the same or its products, while the material is in place.

We shall now describe our method by reference to the annexed drawing, which is a diagrammatic sketch of means which are adapted for the practice of our invention; but we do not limit ourselves to the means here shown, which may be varied as desired without departing from the spirit of our invention.

In the drawing similar characters designate identical parts.

In the drawing Figure 1 is a vertical section cut through a series or group, of wells, showing among other things, the zone of fracture A, the overlying formation B, the surface soil C; also the drilled wells a, a^1, a^2, and a^3, with pipe systems of the different series, connecting respectively with the condenser, tanks and boiler.

Figure 2 is a plan view of the same, showing the group of wells in parallel series. The wells a of each series are shown with the bottoms sloping from a^1 to a^3. The different parallel series may,

[*Price* 1/-]

if desired, have intercommunicating zones of fracture, to any practicable extent, thus constituting a single group, or, according to their degree of contiguity, constitute separate groups.

The overlying formation B, must be of sufficient thickness to resist the vapor-pressure maintained in the zone of fracture A. The drilled wells may be arranged in any form of group desired. The inlet wells a^1 are shown as having steam connections with the boilers g, through the pipe system b. The outlet wells a^2 are used for exhausting the steam and the distillates and are connected with the condenser f, by the pipe system d, as shown.

The outlet wells a^3 are connected with the tank e by the pipe system c, as shown. The different pipes are provided with valves h. The boilers are provided with the usual valves and gauges by which the temperature and pressure of the steam supply can be governed, regulated and controlled.

Our process includes obtaining access to a sub-surface zone in an oil shale formation, which zone may be produced by fracturing the formation at any desired depth and its thickness and area may vary with the richness and thickness of the bituminous shale deposit; two or more such zones as that indicated and marked in the drawing may be developed, the one over the other, and operations carried on simultaneously in any or all of them.

As the oil shale formation, as at present known, is normally so compact as to be impermeable to the circulation of a heating medium, it is necessary to first so fracture the formation in the sub-surface zone, from which the petroleum or shale oil is to be extracted, as to permit of the free circulation throughout the zone, of the gas or vapor used for a heating medium; for this purpose a group of wells are drilled to the zone, which wells are in such contiguity that explosive charges when exploded therein, shall produce intercommunicating fractures throughout the entire area of the sub-surface zone, adapted by their number and extent, to permit of the free circulation of the heating medium, when introduced in any well of the group and its exhaustion through any other well thereof. The wells are of limited cross section, being of the diameters used for drilling for petroleum, except where local conditions may somewhat vary such diameters.

In a series or group of contiguous wells, they are drilled of respectively increasing depth in a given direction in order to permit of the accumulation of the liquid products in the lowest well or wells of the group.

After the necessary wells have been drilled and the sub-surface zone thus defined, explosives are introduced into the several wells and are therein exploded, as may be necessary, to so fracture the formation in the sub-surface zone of operation as to permit of the free circulation therein and throughout the entire area, of the heating medium. All wells or holes not required for further use are then securely sealed so as to resist the vapor pressures maintained in the zone of fracture.

The area of the zone of fracture thus produced is limited and defined only by the lines of fracture thus produced, segregating it from the abutting and contacting surfaces of the unfractured formation.

In the practice of our invention we preferably use steam as a heating medium, though we do not in any way limit or confine ourselves thereto, as any suitable gas or vapor, including furnace gases, which local conditions may render available or desirable, is likewise included within the purview of our invention and wherever the word gas is used in this specification or claims it shall be deemed to include steam or other suitable vapor.

As it is commercially desirable to effect the extraction of the bituminous content of the oil shale with the least expenditure possible of heat energy, we prefer, under usual local conditions, to limit the heat supply to that necessary for the recovery of the heavier products in a liquid state, with distillation of those products which may be vaporized at the temperature thus produced. Such temperature will be found to vary with the material to be treated and must be determined by experiment.

The temperature of conversion of the bituminous material into shale oil occurs at about 350° C. and we preferably carry on the treatment of the material at minimum temperatures required for the extraction of the products.

The heating medium is under governed control as to both temperature and pressure.

The operations may be varied by the regulation of the heat supply, so as to effect:

(*a*) The selective distillation, *in situ*, of the more volatile constituents of a bituminous deposit in an oil shale in the order of their volatilization and the recovery of the respective products, or

(*b*) The collective distillation and recovery of one or more groups of such constituents, or

(*c*) The distillation of the more volatile constituents together with the kerosene content, in one group collectively, including

(*d*) The conversion of the bituminous content of the oil shale into petroleum, or shale oil and the extraction of the heavier constituents of the product and their recovery in a liquid state.

As the distillation of crude petroleum is well established, the regulation of the heat supply necessary for the operations above enumerated are familiar to those skilled in the art.

The temperatures produced in the heated zone for carrying on the above described operations will liquefy the heavier products and permit of their accumulation in the lower part of the zone, from whence they may be recovered by any usual method, preferably by blowing them out with steam pressure.

The temperature of the zone may be increased to the point of vaporization for the heavier oils and base and the entire product may be substantially extracted by distillation.

In the foregoing operations, referring to the drawing, steam is generated in the boilers marked *g* in the drawing, of which there may be more than one, and is conducted through the pipe system *b*, to the well or wells a^1. The boilers are provided with steam gauges of any usual pattern for showing the temperature and pressure of the steam supply and the same is regulated from time to time, for carrying on the various operations hereinbefore set forth, as may be desirable, so that the temperature of the material within the zone may, from time to time be increased to any desired point and maintained thereat, or *vice versa*, for any of the purposes hereinbefore stated. The steam is thus circulated, under sufficient pressure for that purpose, throughout the entire area of the zone, and when not condensed, is exhausted with the distillates through the well a^3 into the pipe *d*, by which it is conducted to the condenser *f*, which may be of any suitable pattern, adapted for the purpose, where the distillates are separated from the steam condensate and the latter, if there be any, returned to the boiler. The liquid products are conducted from the outlet well or wells to the tank *e* as shown.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. The method of treatment of shale and recovery of oil therefrom which consists in obtaining access to a sub-surface zone in an oil shale formation fracturing such formation, introducing into such fractured formation a heating medium and exhausting the same together with the products substantially as herein described.

2. In the treatment of shale and recovery of oil therefrom according to the preceding claim drilling a group of contiguous wells extending into the sub-surface deposit of oil shale adapted for the introduction of explosives and of a heating medium, the exhaust of the latter and the delivery at the surface of the vapourised and liquid products, the zone of fracture being, if desired, limited and determined and adapted to produce a series of intercommunicating fractures substantially as herein described.

3. In the treatment of shale and recovery of oil therefrom according to either of the preceding claims the selective or collective distillation *in situ* of a group of the more volatile products of the bituminous content consisting in circulating throughout the sub-surface zone of fracture a heating medium under governed control as to temperature and pressure regulating the supply of same so as to maintain the temperature in such zone from time to time at such respective points as shall be suitable for progressively vapourising such of said products as may be desired in the order of their point of vapourisation or to maintain the temperature at a suitable point to vapourise any constituent group of such more volatile products as from time to time may be desired substantially as herein described.

4. The method of treatment of shale and recovery of oil therefrom hereinbefore described which consists in drilling a group of contiguous wells in a normally impermeable oil shale formation introducing and exploding charges into such formation in sufficient quantities to produce a zone of fracture therein comprising a series of intercommunicating fractures throughout the zone and rendering the latter permeable to a heating medium sealing such wells as are not thereafter required, introducing a heating medium supply under governed control as to temperature and pressure thereby heating the bituminous content of the material

converting the same into petroleum, the vapourisation of the more volatile and the liquefaction of the heavier products through other wells, substantially as herein described.

5. The method of treatment of shale and recovery of oil therefrom including circulating a heating medium from the surface, substantially as hereinbefore described and with reference to the accompanying drawings for the purposes specified.

Dated the 10th day of December, 1919.

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[This Drawing is a reproduction of the Original on a reduced scale]

Fig. 1.

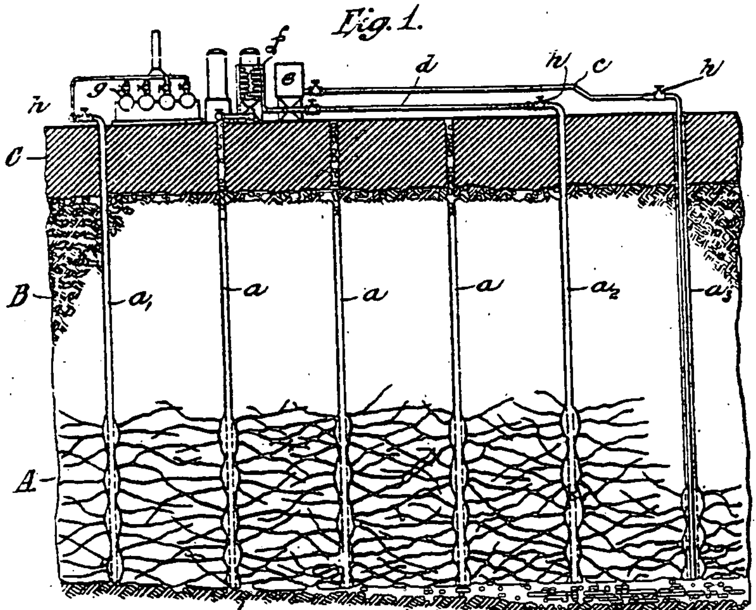
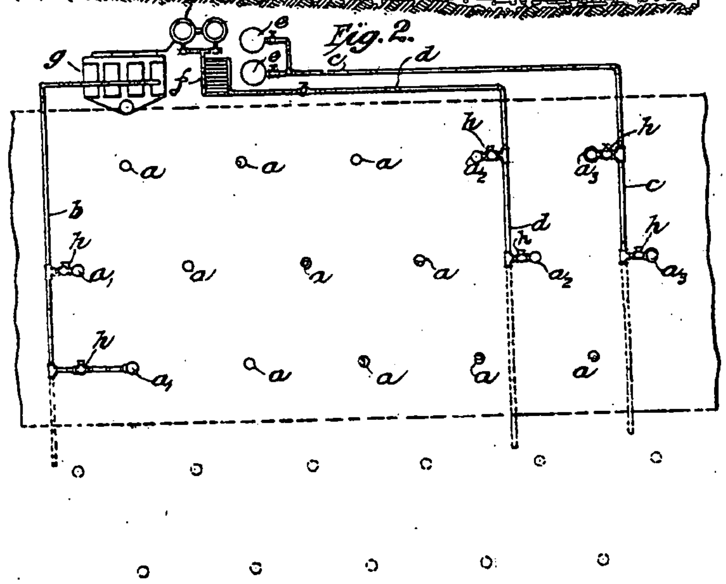


Fig. 2.



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PATENT SPECIFICATION

674,082

Inventor:— FRANK ARCHER WILLIAMS.

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Complete Specification Published: June 18, 1952.

Index at Acceptance:—Class 55(ii), M.

COMPLETE SPECIFICATION.

Improvements in or relating to the Underground Gasification of Coal.

We, NATIONAL RESEARCH DEVELOPMENT CORPORATION, a British Corporation, established by Statute, of 1, Tilney Street, London, W.1, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to the underground gasification of coal.

In the known systems for the underground gasification of coal, a stream of gasifying medium, such as air or mixtures of air with oxygen and/or steam or a mixture of steam and oxygen, is passed through a suitable channel in the coal seam, for example black or brown coal or lignite. It has been found that in such systems the calorific value of the gas obtained is lower than has been anticipated and that in certain cases the oxygen finds its way in the elemental state through the gasification zone and appears in the effluent gas. The presence of such oxygen in the final gas is a clear indication that contact between the coal and the gasifying medium is not as satisfactory as desirable and this is supported by the low calorific value of the gas generally obtained which results from low gasification temperatures due to the same absence of efficient contact, coupled with partial combustion of the gas formed by oxygen which is finding its way through the gasification zone.

This disadvantage is obviated according to the present invention by the provision of means so situated in proximity to the gasification zone as to impart a swirling motion to the stream of gasifying medium so that closer contact between the stream and the coal face is obtained at the point of gasification.

The invention is illustrated diagrammatically in the drawing accompanying the Provisional Specification in which Figure 1 represents a complete underground gasification system and Figure 2 represents the means for imparting a swirling motion to the gaseous stream.

Referring to the drawings, the coal A is undergoing gasification in the passage B through which a gasifying medium is conducted through the inlet pipe C to the outlet pipe D. At the point E in the passage B immediately adjacent to the lower end of the inlet pipe is situated the swirler shown in Figure 2. The swirler comprises a number of vanes F arranged radially in a housing G, the vanes being set at a suitable angle to impart the necessary swirl to the gases.

The form of swirler illustrated in Figure 2 is given merely by way of example, and other forms such as suitably designed nozzle passages, mechanical paddles, etc., may be employed if desired.

The form of swirl designed to produce more intimate contact between the gaseous stream and the coal face may be a simple single core vortex or composed of several vortices with their axes of rotation lying in the direction of the gas stream.

For efficient contact, each molecule of reacting gas in the gasifying medium must be brought into close proximity with the fuel constituting the walls of the passage and at the same time reacted gases in the boundary layer should be removed. Such conditions might be achieved by employing a highly turbulent state in the reacting gases i.e. a very high Reynolds number. Such a highly turbulent state, however, results in a high pressure drop and necessitates a length/diameter ratio for the passage to be about 500 or more. In the present invention, the desired contact is achieved by operating at

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Reynolds numbers, based on the effective hydraulic diameter of the gas passage, up to 15,000 i.e. broadly in the range just above streamline flow. Imposed upon the main flow is a swirling motion (or motions) arranged so that the axis of rotation is in the same direction as that of the gas passage through the coal.

The imposing of a swirling motion on the gaseous flow, in accordance with the invention has the following advantages:—

(1) The gas molecules are caused to traverse a spiral path with the result that they are retained longer (for a given local gas velocity) in a given length of passage i.e. the maximum effect is achieved for a given length to effective diameter ratio of the passage.

(2) The inevitable decay of swirl takes place due to wall friction, leads to longitudinal pressure gradients in the air passage; these gradients lie in the same direction as the stream along the walls of the passage but against the stream at the core of the passage. The result is that the profile of velocity in the direction of the passage is more favourable than for swirl-free flow in that the velocity is high near the walls and decelerated in the core. The tendency for unreacted gas to pass untouched through the centre parts of the passage is therefore checked. Indeed this effect may be exploited where desirable to produce an actual flow reversal near the centre of the passage so that incompletely reacted products may be returned, in part, for further contact with the walls of the passage.

(3) The centrifugal gradient of pressure maintained outwards by the swirl will prevent unreacted gas striking through at sudden enlargements of the passage area since the swirl maintains close contact of the high velocity stream with the rapidly diverging walls.

(4) The net result of these effects is that the length of passage required for effective gasification is greatly reduced, hence total heat losses by conduction to the surrounding rock and coal are diminished and higher temperatures result in the reaction zone giving rise to gas of higher calorific value.

(5) All the advantages which the swirl has in bringing gas molecules into contact with the coal apply equally to the distribution of heat by heat transfer throughout the reaction zone.

What we claim is:—

1. In a system for the underground gasification of coal in which a stream of gasifying medium (such as air, or air mixed with oxygen, or a mixture of steam and oxygen) is passed through the coal seam, the provision of means so situated in proximity to the gasification zone as to impart a swirling motion to the said stream so that closer contact between the stream and coal face is obtained at the point of gasification.

2. A system for the underground gasification of coal comprising a channel extending through the coal system, an inlet pipe or shaft for supplying a gasifying medium (such as air, or air mixed with oxygen, or a mixture of steam and oxygen) to one end of the said channel, an outlet pipe or shaft at the other end of the said channel by which the effluent gas is collected, and a swirler in the said channel adjacent to the said inlet pipe for imparting a swirling motion to the stream of gasifying medium, the said swirler being in the form of fixed or rotating vanes or paddles, suitably arranged nozzles or the like.

3. A system for the underground gasification of coal substantially as hereinbefore described or substantially as illustrated in the drawing herein referred to.

A. F. BURGESS.
Chartered Patent Agent.
Agent for the Applicant.

PROVISIONAL SPECIFICATION.

Improvements in or relating to the Underground Gasification of Coal.

We, NATIONAL RESEARCH DEVELOPMENT CORPORATION, a British Corporation, established by Statute, of 1, Tilney Street, London, W.1, do hereby declare the nature of this invention to be as follows:—

It is well known that it has been proposed to gasify coal seams (whether of black or brown coal or lignite) underground by the passage through suitable channels of air or mixtures of air with oxygen and/or steam, or a mixture of steam and oxygen and this process is being operated on a large scale in various parts of the world. From the results of these operations, it has become clear that in general the calorific value of the gas obtained is lower than had been anticipated, and in certain cases, it has been found that oxygen is finding its way in the elemental state through the gasification zone and is appearing in the effluent gas. The presence of such oxygen in the final gas is a clear indication that contact between the coal being gasified and gasifying medium is not as satisfactory as desirable and this is supported by the low calorific value of the gas generally obtained which

results from low gasification temperatures due to the same absence of efficient contact.

For efficient contact, each molecule of reacting gas in the gasifying medium must be brought into close proximity with the fuel constituting the walls of the passage and at the same time reacted gases in the boundary layer should be removed. Such conditions might be achieved by employing a highly turbulent state in the reacting gases i.e. a very high Reynolds number. Such a highly turbulent state, however, results in a high pressure drop and restricts the throughput. Pressure energy is wasted in small scale vorticity which is ineffective for transfer of gas from the core of the passage to the walls.

In the present invention, the desired contact is achieved by operating at Reynolds numbers, based on the effective hydraulic diameter of the gas passage, up to 15,000 i.e. broadly in the range just above streamline flow. If Reynolds numbers of this order are exceeded it will be necessary for the length/diameter ratio of the passage to be above about 500. Imposed upon the main flow is a swirling motion (or motions) arranged so that the axis of rotation is in the same direction as the major axis of the passage through the coal. Such a swirl has the following advantages.

(1) The gas molecules are caused to traverse a spiral path with the result that they are retained longer (for a given local gas velocity in a given length of passage i.e. the maximum effect is achieved for a given length to effective diameter ratio of the passage.

(2) The inevitable decay of swirl which takes place due to wall friction, lead to longitudinal pressure gradients in the air passage; these gradients lie in the same direction as the stream along the walls of the passage but against the stream at the core of the passage. The result is that the profile of velocity in the direction of the passage is more favourable than for swirl-free flow in that the velocity is high near the walls and decelerated in the core. The tendency for unreacted gas to pass untouched through the centre parts of the passage is therefore checked. Indeed this effect may be exploited where desirable to produce an actual flow reversal near the centre of the passage so that incompletely reacted products may be returned, in part, for further contact with the walls of the passage.

(3) The centrifugal gradient of pressure maintained by the swirl will prevent unreacted gas striking through at sudden enlargements of the passage area since the swirl maintains close contact of the high velocity stream with the rapidly diverging walls.

(4) The net result of these effects is that the length of passage required for effective gasification is reduced, hence total heat losses by conduction to the surrounding rock and coal are diminished and higher temperatures result in the reaction zone giving rise to gas of higher calorific value.

(5) All the advantages which the swirl has in bringing gas molecules into contact with the coal apply equally to the distribution of heat by heat transfer throughout the reaction zone.

6. The swirl designed to produce these effects may be a simple single core vortex or composed of several vortices with their axes of rotation lying in the direction of the gas stream. Such swirl patterns may be produced by suitably designed nozzle passages, mechanical paddles, etc. In the accompanying drawing one method of applying swirl is indicated. In Fig. 1 the seam A is undergoing gasification in the passage B through which a gasifying medium is passing from the inlet pipe C to the outlet pipe D. At the point E immediately adjacent to the inlet pipe is situated a swirler. This consists of the device shown in Fig. 2 i.e. a number of vanes F arranged radially in a housing G which is arranged at right angles to the flow of gas in passage B. The vanes are set at an angle to impart the necessary swirl to the gases.

Dated the 15th day of June, 1949.

F. A. WILLIAMS.

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Published at The Patent Office, 25, Southampton Buildings, London, W.C.2, from which copies may be obtained.

674,082 PROVISIONAL SPECIFICATION

1 SHEET *This drawing is a reproduction of the Original on a reduced scale.*

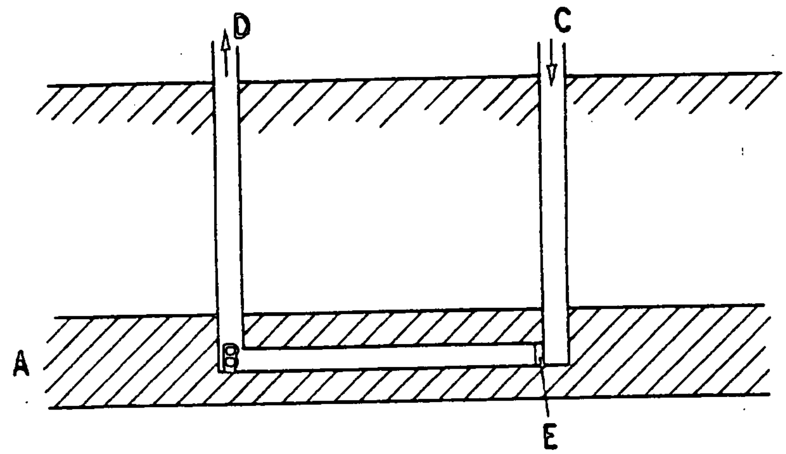

Fig. 1.

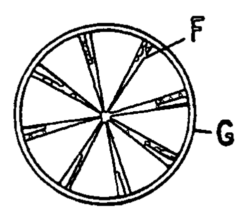

Fig. 2.